THE PRACTICAL IMPACT OF DIGITAL MANUFACTURING:

RESULTS FROM RECENT INTERNATIONAL EXPERIENCE

INTERIM REPORT | SEPTEMBER 2018

A study for Innovate UK by Policy Links, Institute for Manufacturing (IfM), University of Cambridge

Contributors:
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Institute for Manufacturing (IfM), University of Cambridge

The Institute for Manufacturing (IfM) is part of the Department of Engineering at the University of Cambridge. Comprising some 240 people (excluding taught course students), it:

- Conducts research across the full range of manufacturing issues, from understanding markets and technologies, through product and process design, production and supply chain design and operation, through-life service, to economics and policy.
- Conducts practical, problem-based, education to develop leaders and managers for industry.

Policy Links, IfM Education and Consultancy Services (IfM ECS)

IfM ECS is owned by the University of Cambridge. It transfers new ideas and approaches developed by researchers at the Institute for Manufacturing (IfM) to industry and government through a programme of education and consultancy services. Profits are gifted to the University of Cambridge to fund future research activities. Policy Links is part of IfM ECS and is the knowledge transfer unit of the Centre for Science, Technology & Innovation Policy (CSTI). Policy Links works closely with UK and international policy practitioners to develop more effective industrial innovation policies.

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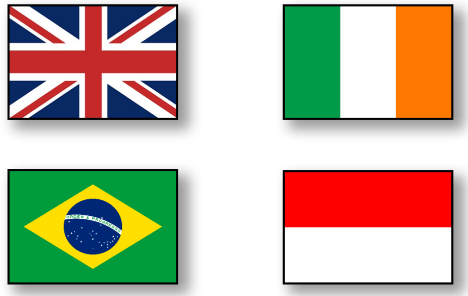
Cambridge, UK | September, 2018

SELECTED WORK ON INDUSTRIAL DIGITALISATION / INDUSTRY 4.0

POLICY LINKS AND CENTRE FOR SCIENCE, TECHNOLOGY & INNOVATION POLICY (CSTI)

2018

- **Study on Digitalisation of the Manufacturing Sector and the Policy Implications for Ireland –** Department of Business, Enterprise and Innovation (DBEI)
- **Expert paper for "Industry 2027 – Risks and Opportunities for Brazil in the face of disruptive innovations" –** Brazil's National Confederation of Industry (CNI) – Link
- **'Supporting Technological Transformation in Indonesia' –** Asian Development Bank (ADB) – Link



2017

- **'Review of International Policy Approaches to Value Chain Capability Development' –** UK Department for Business, Energy & Industrial Strategy (BEIS)
- **Book Chapter: 'Manufacturing R&D Policies for the Next Production Revolution: An International Review of Emerging Research Priorities and Policy Approaches' –** Organisation for Economic Co-operation and Development (OECD) – Link
- **'Emerging Trends in Global Advanced Manufacturing' –** United Nations Industrial Development Organization (UNIDO) – Link
- **Contribution to the 'Readiness for the Future of Production Report 2018'** – World Economic Forum's – Link

UNIDO UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

OECD BETTER POLICIES FOR BETTER LIVES

ADB ASIAN DEVELOPMENT BANK

AIMS OF THE PROJECT

Background

Innovate UK is seeking to further enhance the evidence base on the potential gains that might be achieved through digital adoption.

Most estimates of the impact of digital applications in manufacturing produced to date have focused on ***expected*** rather than ***observed*** impact, primarily on the basis of crude macroeconomic extrapolations and survey data.

The Made Smarter Review estimates that UK industry could achieve a **25% increase in productivity through digital adoption by 2025**.

Opportunities exist to further enhance the evidence base on the practical potential of digital manufacturing by reviewing findings emerging from recent digital adoption efforts and studies from around the world.

Aims

To collect and analyse evidence on potential improvements derived from the adoption of digital technologies in the manufacturing sector, and discuss potential implications for the UK.

STRANDS OF WORK

The study encompassed three strands of work:

1. Sources of evidence and data gathering
- Identification & review of sources of evidence
- Gathering of indicators (impact of digital adoption)
- Classification of raw data

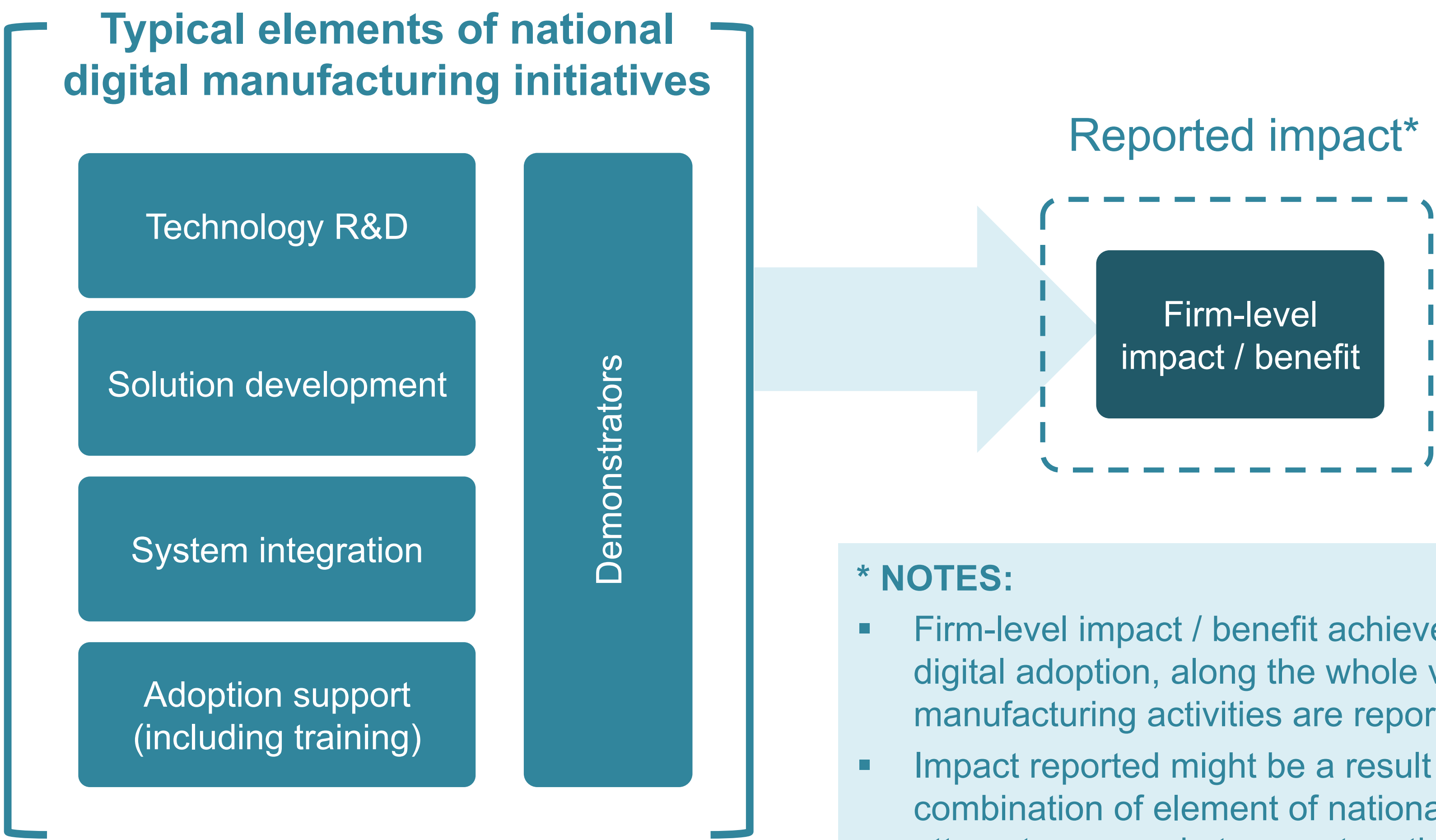
2. Structuring & analysis of evidence base
- Structuring of data using appropriate frameworks
- Characterisation of international policy approaches and initiatives
- Summary of findings and discussion of implications for UK industry

3. Workshop with selected stakeholders
- Discussion of results
- Capturing views from UK stakeholders
- Discussion of implications for the UK

Evidence on practical impact of digital adoption in manufacturing

NOTES ON APPROACH

SCOPE OF THE PROJECT



*** NOTES:**

- Firm-level impact / benefit achieved, through digital adoption, along the whole value chain of manufacturing activities are reported.
- Impact reported might be a result of the combination of element of national initiatives; no attempts are made to report on the impact of any individual element.

VARIETY OF NATIONAL INITIATIVES (NON-EXHAUSTIVE)

Development-focused

Adoption-focused

Type 1 (e.g. US, Australia, Canada)

Research to improve functionality of application / next-generation → Pilot testing in 'model factories' / pilot lines → Pilot application in selected firms

Type 2 (e.g. Japan)

Private sector consortia / working groups identify common issues → Work with developer ("platformer") to produce solution → Adoption by firms working group and wider consortia

Type 3 (e.g. Singapore, Korea)

Development of suite of applications made available by RTO or Innovation Centre→ Firms select relevant applications → Firms have access to grants to support application → Adoption support to firms including training

Type 4 (e.g. Spain)

Funding agency → Firm receives funding → Technology acquisition (typically off-the-shelf / open market/ pre-selected private vendors) → Adoption by firm

Type 5 (e.g. Italy)

Tax break → Capital equipment acquisition by firm → Adoption by firm

NOTES ON APPROACH / LIMITATIONS

SAMPLING

- Data informing the study was obtained from a limited number of countries (the primary focus was the cases reported by national Digital Manufacturing initiatives in countries including:, China, France, Germany, Korea, Japan, Singapore, US).
- The initiatives surveyed largely focus on deployment of applications in firms (high-level TRLs), not development of new applications (lower TRLs).
- Results reported were obtained primarily from applications in Small and medium-sized enterprises (SMEs).
- Estimations of impact are mostly self-reported by firms.
- Some results might have been obtained in controlled environments.

IMPACT MEASUREMENT

- Digitalisation efforts might involve activities in different operational and strategic aspects of a firm's operation – not all the benefits achieved can necessarily be attributed to technology.
- In general, estimates assume that business models remains the same.
- Further analyses are required to account for potential time lags (between adoption and achievement of impact).
- Some digital applications could reshape industrial organisation and value chains; their impact might be very different if that happens.

NATIONAL DIFFERENCES

- Results are context dependent: care must be taken in using results from one country as the basis for estimations of impact in a different one (different countries, different sectors).

RESULTS

Indicators of the practical impact of digital manufacturing were obtained from three main sources:

a) STRATEGIES & STUDIES FROM NATIONAL INITIATIVES
b) USE CASES (FIRM-LEVEL ADOPTION)
c) POLICY & ACADEMIC LITERATURE

STRATEGIES & STUDIES FROM NATIONAL INITIATIVES

This section presents estimations of the impact of digital adoption found in major national government-supported initiatives around the world.

These include:

- **Targets established by the initiatives (*expected* impact)**
- **Impact estimated by policy studies (*expected* impact)**
- **Results obtained by firms supported by the initiatives (*observed* impact)**

Data presented in this section was taken from original national sources. No attempt has been made to evaluate accuracy or methodological approaches. Typically, estimations are produced by government agencies or are taken from studies commissioned to private consultancies.

SELECTED INDICATORS ON IMPACT OF DIGITALISATION (SUMMARY)

Expected impact	AUSTRALIA	AUSTRIA	CANADA	GERMANY	SPAIN
National productivity	-	**20%** Productivity gains for the next 5 years with Industry 4.0 applications [33]	-	**30%** Productivity gains of 'up to 30% by 2025' with the adoption of digital technologies in the industry [28]	-
Manufacturing efficiency (factory-level)	-	**€5-10 billion** Efficiency potential with the adoption of Industry 4.0 technologies 2015-2025 [32]	-	**3.3%** Annual efficiency gains with the adoption of digital technologies in the industry, 2016-2020 [28]	-
Value added	**AU$140-250 billion** Digital technologies contribution to GDP from 2010-2025 [29]		**C$34 billion** Contribution of the "Digital Technology Supercluster" to GDP by 2025 [9]	**€425 billion** Cumulative value added digitalizing industry, 2016-2020 [28]	**€120 billion** Accumulated growth in value added with the adoption of digital technologies, 2017- 2025 [21,22]
Jobs	-	-	**50,000** Created by the "Digital Technology Supercluster", 2017-2027 [9]	**390,000** Created by Industry 4.0 from 2015-2025 [19]	**1.25 million** Created in the next 5 yrs with the adoption of digital technologies [21, 22]
Manufacturing output	**25%-35%** (Above trend by 2026 across advanced manufacturing) [10]	-	-	-	**€35 billion** Accumulated growth in GDP with the adoption of digital technologies 2017-2020 [21]
Cost reduction	-	**2.9%** Per year, for the next five years from Industry 4.0 [33]	-	**2.6%** Annually with the adoption of digital technologies in the industry, 2016-2020 [28]	-
Other	-	**2.6%** Average turnover increase per year, over the next 5 yrs from Industry 4.0 [33] **€6-14 billion** Sales potential by 2025 from Industry 4.0 technologies [32]	-	-	-

Note: Data taken from original national sources. No attempts have been made to evaluate accuracy or methodological approaches.

SELECTED INDICATORS ON IMPACT OF DIGITALISATION (SUMMARY)

		JAPAN	KOREA	SINGAPORE	US
Expected impact	National productivity	**Over 2%** Labour productivity gains in manufacturing industries [38]	-	**30%** Boost in labour productivity by 2024 with the adoption of Industry 4.0 [24]	-
	Manufacturing efficiency	-	-	**30-40%** (local companies expected output increment with the adoption of digital technologies) [27]	-
	Value added	**$270 billion** Value added by advanced manufacturing by 2020 [30]	-	-	-
	Jobs	-	-	**22,000** (jobs created with the adoption of Industry 4.0 with average salaries up to 50% higher, from 2017- 2024) [24,26]	-
	Manufacturing output	-	**2%** Potential growth of output in major industries "when opportunities given by I4.0 are suitable utilised" [28]	**S$36b** (Total manufacturing output and revenue by 2024 with the adoption of Industry 4.0) [24]	-
	Cost reduction	-	-	-	-
	Other	-	**30,000** 'Smart Factories' for SMEs by 2025	-	-
Observed impact	National productivity		-	-	-
	Manufacturing efficiency		**30%** Result from 2,800 digital applications primarily in SMEs [28]	**30%** Improvements in efficiency achieved by local companies with the adoption of digital technologies [26] **15-20%** Increment in output observed by SMEs that have applied digital technologies[27]	**20%** (primarily SME results, case studies) [4,5]
	Cost reduction		**15%** Result from 2,800 digital applications primarily in SMEs [28]	-	-
	Other		**45%** reduction defective product ratio **16%** reduction in delivery time Result from 2,800 digital applications primarily in SMEs [28]	-	-

Note: Data taken from original national sources. No attempts have been made to evaluate accuracy or methodological approaches.

OBSERVATIONS

The international review of national digital manufacturing initiatives identified a variety of indicators used to report the *expected* and *observed* impact driven by industrial digitalisation. While not reported here, qualitative measures such as *competitiveness*, *business confidence*, and *sustainability* are also often cited.

EXPECTED IMPACT

In terms in ***expected impact*** countries provide estimations of national-level indicators such as *productivity*, *value added* and *jobs*.

- **Productivity*:** Estimates cited by the national governments of the potential impact of digitalising industry include productivity gains of up to **30% by 2025 in Germany** and **30% by 2024 in Singapore**. In **Japan**, the government estimates that growth in labor productivity in manufacturing could be increased by more than **2% annually**, citing as a key driver a expected doubling of robot use by 2020.
- **Value added:** The most common indicator used in the sample of countries surveyed, however, is **value added**. Estimates vary significantly, reflecting differences between the size of national economies.
- **Jobs:** Despite common perceptions about the potential negative impact of digitalisation on jobs, all estimations identified forecast that digitalising industry will lead to the creation of new jobs.

OBSERVED IMPACT

Fewer countries have reported data on ***observed impact,*** reported at the firm level.

- Interestingly, both **Singapore** and **Korea** report the same levels of improvements in manufacturing efficiency (**30%)** in the samples of firms analysed.
- The case of **Korea** is particularly interesting. Systematic efforts have been made to evaluate the firm-level impacts of digital adoption observed by the firms supported by a major national programme, the *Korea Smart Manufacturing Initiative.*
- Perhaps not surprisingly, **no estimations of observed national productivity growth** are presented in any of the countries surveyed.

* Caution should be taken to distinguish between *national-level 'productivity'* and *firm-level 'manufacturing efficiency'*.

STRATEGIES & STUDIES FROM NATIONAL INITIATIVES

This section presents a brief comparison of the funding levels and sources of major national digital manufacturing initiatives.

SELECTED MANUFACTURING DIGITALISATION INITIATIVES – BUDGET COMPARISON (1/2)

Country	GDP (UK=100)	Initiative	Source of funding	Funding levels	Funding as % of GDP (per year)
Korea	58.4	The Korea Smart Factory Initiative	Public (MOTIE)	$189.3 million from 2017 to 2020 [19].	0.003
Germany	140.2	Plattform Industrie 4.0	Government (Ministry of Economic Affairs and Ministry of Education and Research) Private contributions (50% SMEs, <50% Large)	€200 million in funding allocated by BMBF and BMWI complemented by industry contributions (2011-2020) [15].	0.0006
United States	739.4	Digital Manufacturing and Design Innovation (DMDII) [Part of the Manufacturing USA Institutes]	Co-Funding public-private	5-year cooperative agreement, $70 million federal funding and over $180 million matching funding from partners [36].	0.0002
Japan	185.8	Connected Industries	Public (METI)	$ 171.6 million included in the FY 2018 budget of the Ministry of Economy, Trade and Industry to promote Connected Industries [40].	0.0076
		Robot Revolution Initiative(RRI)	Public and private sectors	¥ 100 billion investment expected in robots during the period 2015-2020 [39].	
Singapore	12.4	Automation support package	Government	$400 million over the next three years [25].	0.0668
		(FoM) Initiavei4.0 strategy	Government (EDB, a-Star, MoT, NEA, MoH, MoHA)	S$450 million to support National Robotics Programme over next 3 years [25].	
		'Model Factory' initiative	Public-private partnership	Model Factory@SIMTech: Up to S$60 million joint lab [25].	

SELECTED MANUFACTURING DIGITALISATION INITIATIVES – BUDGET COMPARISON (2/2)

Country	GDP (UK=100)	Initiative	Source of funding	Funding levels	Funding as % of GDP (per year)
Australia	50.5	Industry's Growth Centers Initiative	Australian Government (Department of Industry, Innovation and Science)	The Industry Growth Centres Initiative has funding of A$232.0 million over six years from 2017-18 [37].	0.0022
Canada	63.0	Innovation Superclusters Initiative	Private and Public	C$950 mi to support business-led innovation between 2017-2022 [8].	0.0073
Austria	15.9	Platform Industry 4.0	Basic Seed funding provided by 6 founding members and membership fees (50% from the Austrian Ministry of Transport, Innovation and Technology; remaining 50% provided by the other members) [13].	Founding members contribution: €300,000 per year for 3 years; €200,000 provided by the membership fees (forecast for 2017) [13].	0.0253
		Production of the Future (Research)	Government (Federal Ministry of Transport, Innovation and Technology)	Over €450 million (2011-2015). *Production of the Future* provides €25 millions every year in funding for research projects [12, 14].	
Spain	50.0	Industria Conectada	Government (30-50% for SMEs, 20-40% for Large) [21].	€100 million in 2016 [22].	0.009

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USE CASES IDENTIFIED & ANALYSED

1,038 individual cases
Identified in
>70 national digital adoption initiatives
from around the world

Assessment of relevance →

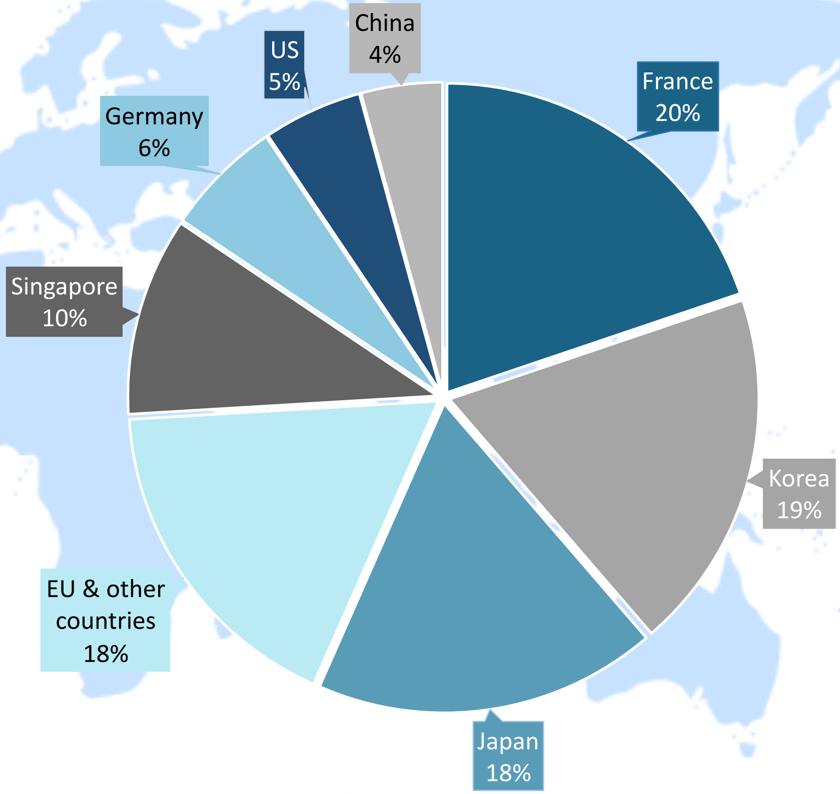
212 cases selected for analysis

USE CASES IDENTIFIED & ANALYSED

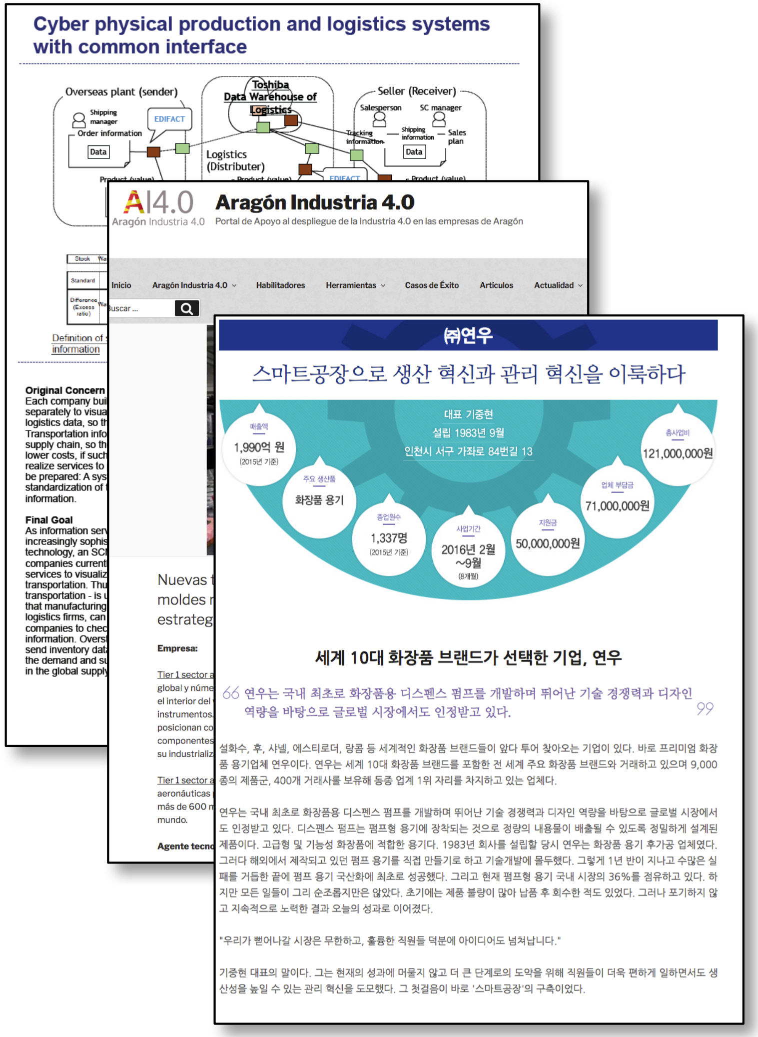
Major initiatives reviewed

- **France:** Alliance Industrie du Futur
- **Korea:** Smart Factory Initiative
- **Japan:** Industrial Value Chains Initiative
- **EU:** I4MS initiative: ICT Innovation for Manufacturing SMEs
- EU Smart Anything Everywhere Initiative
- **Singapore**: Tech-Depot Initiative
- **Germany**: Plattform Industrie 4.0
- **US**: Industrial Internet Consortium
- **US**: America Makes
- **Made in China 2025:** National Intelligent Manufacturing Pilot Programme

Origin of cases



USE CASES



Typical case structure

COMPANY NAME / SOLUTION NAME

Problem

Digital solution(s) used

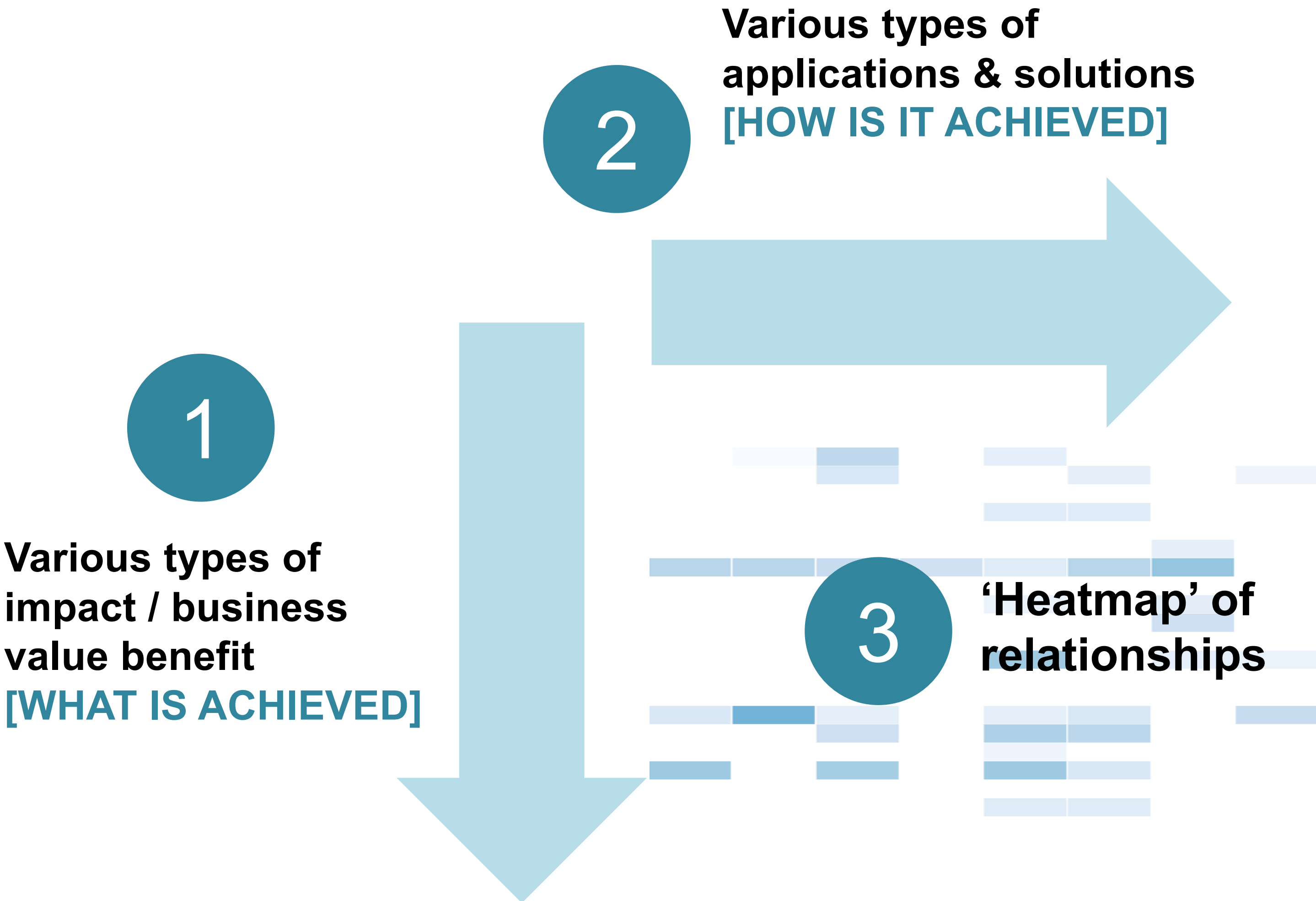
Impact / benefit

- Tangible/intangibles
- Qualitative and quantitative

Etc.

Focus of this project: quantitative indicators

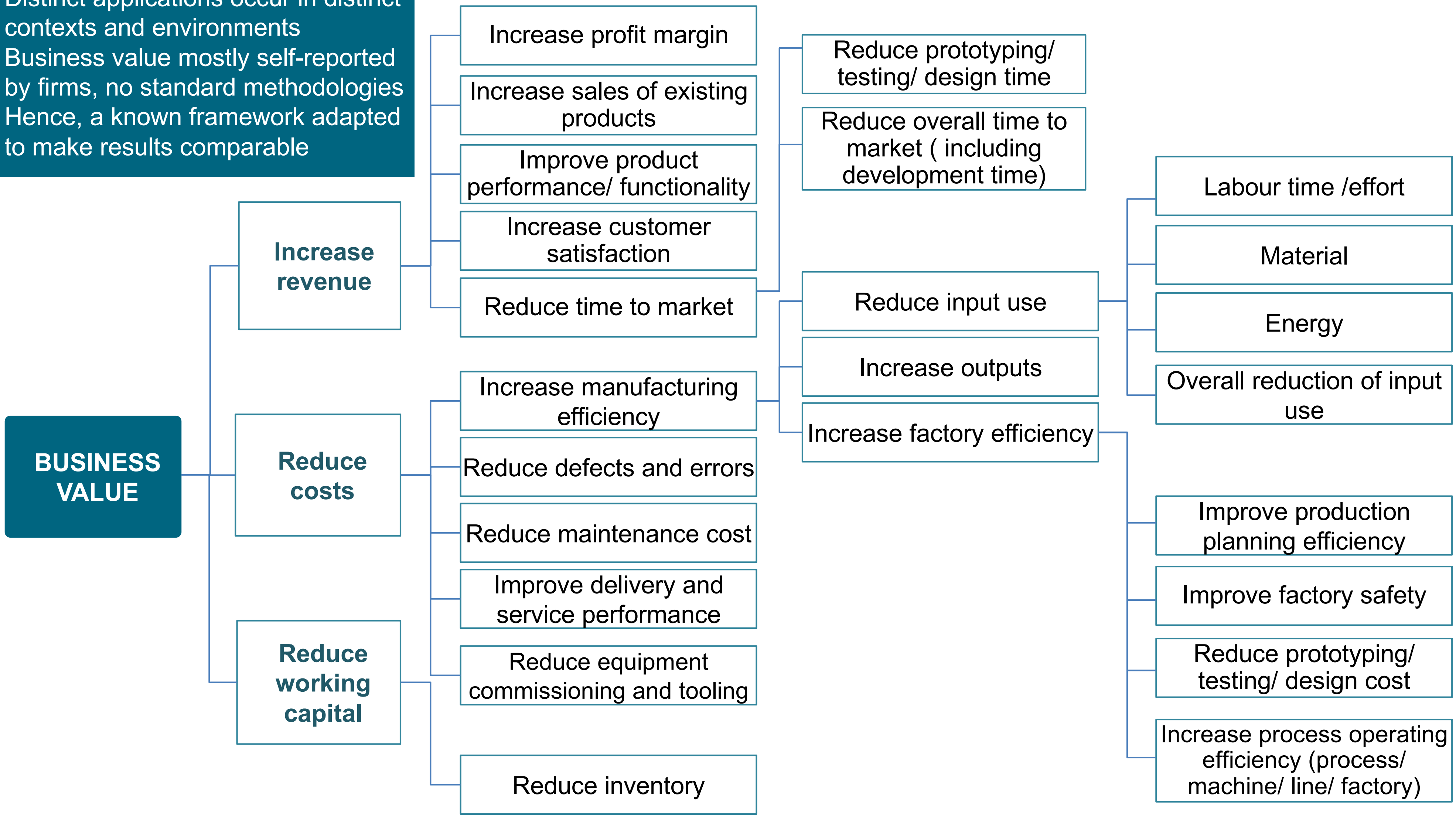
FINDINGS


2
Various types of applications & solutions
[HOW IS IT ACHIEVED]
1
Various types of impact / business value benefit
[WHAT IS ACHIEVED]
3
'Heatmap' of relationships

(1) BUSINESS VALUE

(1) CLASSIFYING IMPACT ON BUSINESS VALUE

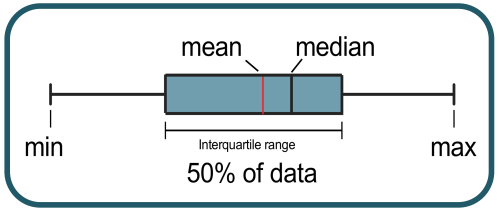
- Distinct applications occur in distinct contexts and environments
- Business value mostly self-reported by firms, no standard methodologies
- Hence, a known framework adapted to make results comparable



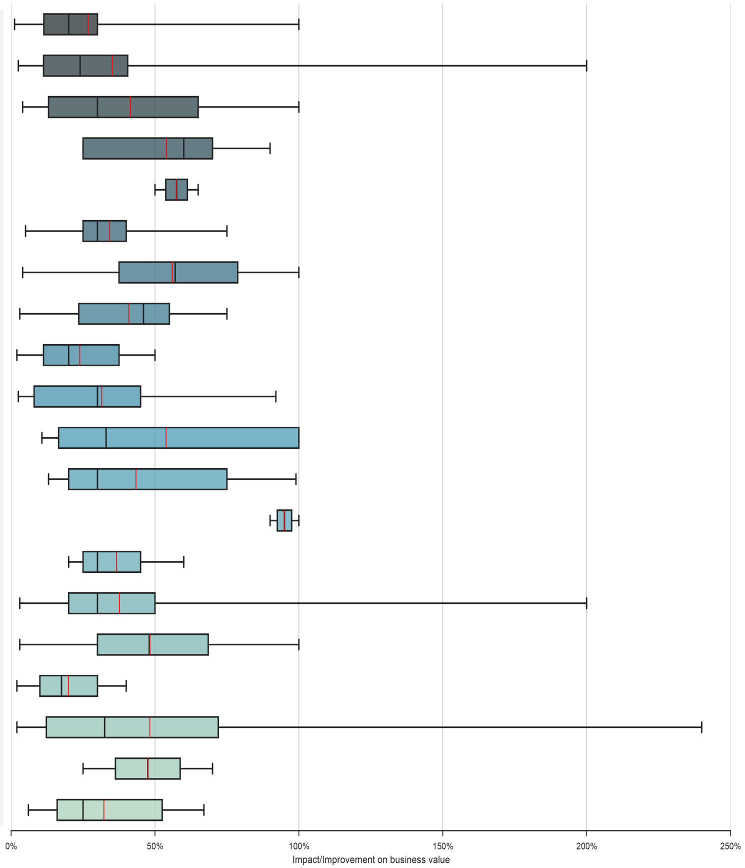
Adapted from: Wiliam P. King (2015). Digital Manufacturing. Digital Manufacturing & Design Innovation Institute presentation

OBSERVED RESULTS: BUSINESS VALUE VIEWPOINT

- Distinct applications occur in distinct firms, contexts and environments
- Business value mostly self-reported by firms without standard methodologies
- Hence, inherent variability in reported data
- However, despite this variability, collected data evidences positive general impact in business value



BUSINESS VALUE					% instances
	Increase revenue	Increase profit margin			4.3%
		Increase sales of existing products			5.3%
		Improve product performance / functionality			1.7%
		Increase customer satisfaction			1.2%
		Reduce time to market		Reduce prototyping/testing/design time	0.5%
				Reduce overall time to market (including development time)	3.1%
	Reduce costs	Increase manufacturing efficiency	Reduce input use	Labour (time, effort)	16.1%
				Material	2.7%
				Energy	6.3%
				Overall reduction of input use	2.7%
			Increase outputs		1.7%
			Increase factory efficiency	Improve production planning efficiency	3.1%
				Improve factory safety	0.5%
				Reduce prototyping/testing/design cost	0.7%
				Increase process operating efficiency (process/ machine/ line/ factory)	30.1%
		Reduce defects and errors			9.6%
		Reduce maintenance cost			1.2%
		Improve delivery and service performance			5.8%
		Reduce equipment commissioning and tooling			0.5%
	Reduce working capital	Reduce inventory			2.9%



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KEY FINDINGS

Business value areas where more cases reported improvements*:

- Increase in process efficiency (single, multiple process + whole factory efficiency): **~ 30% of instances**
- Reduction of labour costs: **~ 16% of instances**
- Reduction of defects and errors: **~ 10% of instances**
- Reduction of energy costs: **~ 6% of instances**
- Improved delivery & services performance: **~ 6% of instances**

Business value areas with bigger benefit/improvement* † :

- Reduction of labour costs: **> 55%**
- Reduction of defects and errors: **> 45%**
- Reduction in material costs: **> 45%**
- Increase in outputs: **> 30%**
- Improved delivery & service performance: **> 30%**

NOTES:
*** Only cases with >5 instances are reported (total number of instances: ~420)**
† Median

(2) APPLICATIONS & SOLUTIONS

CLASSIFYING DIGITAL APPLICATIONS & SOLUTIONS

Manufacturing product & process design	Encompasses all of the functions and processes associated with conceiving and developing new (and improved) products and manufacturing processes, to the point of readiness for manufacturing execution.	• Product design & definition • Product development • Process design & definition
Manufacturing process	Encompasses all of the functions associated with translating product designs into finished goods.	• Process quality management • Material pre/post processing • Input & waste management • Material/product processing • Assembly • Testing, inspection, validation • Packaging & shipping • Maintenance management • Process control and optimisation (including machine operation monitoring)
Manufacturing infrastructure	Encompasses all of the functions that support the creation of the product, both directly and indirectly.	• Operations infrastructure
Enterprise management	Encompasses all of the functions associated with managing the operation of a manufacturing business entity.	• Product and service quality management • Supply chain management • Production planning and control • Product lifecycle management • Staff and Workflow management • Demand forecasting/ inventory and delivery management • Resource management • Business operations

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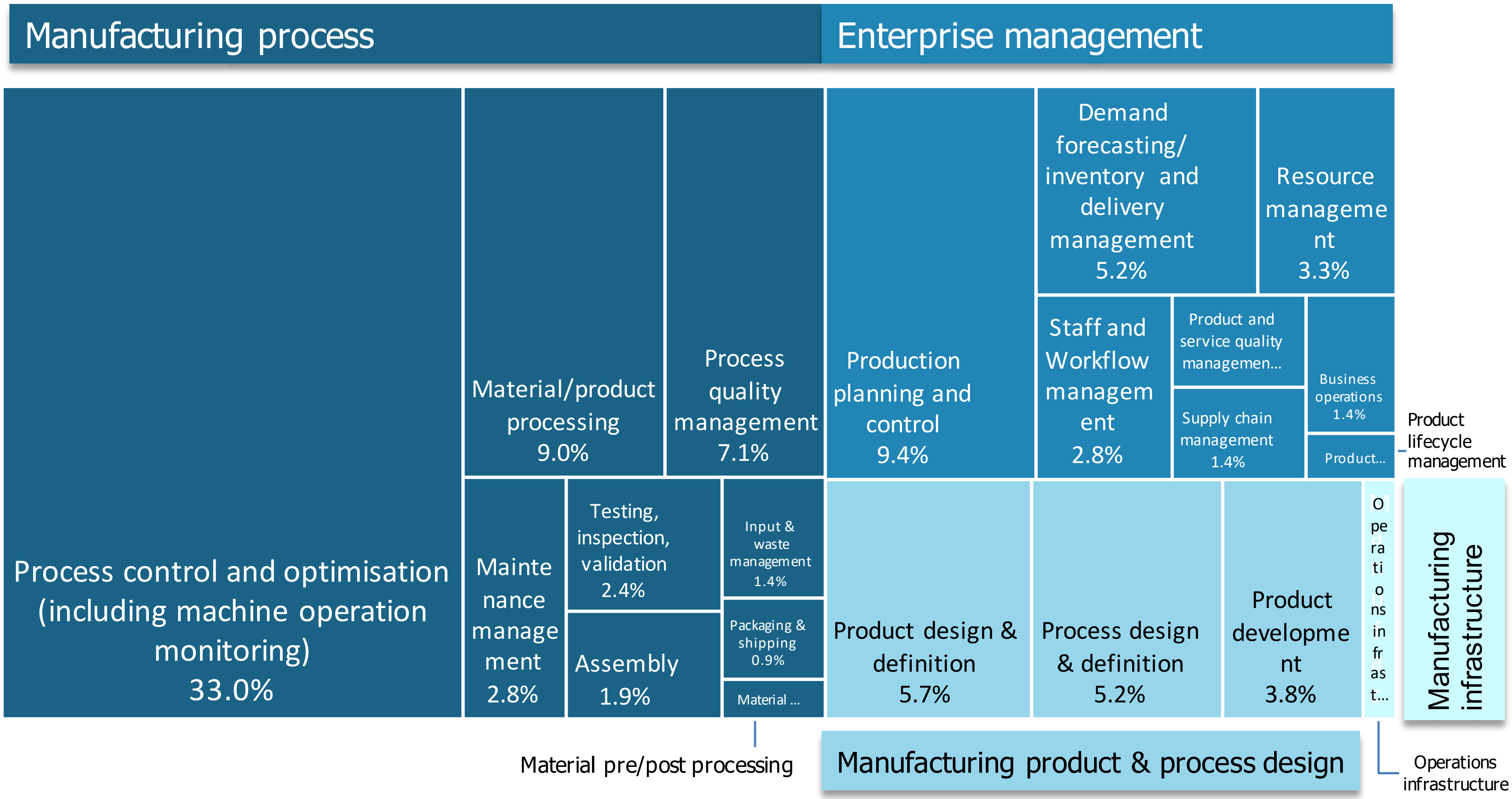
Note: Manufacturing taxonomy adapted from Integrated Manufacturing Technology. 21st Century Manufacturing Taxonomy: [IMTI, 2003].

USAGE OF APPLICATIONS & SOLUTIONS

SHARE OF CASES REPORTED BY FUNCTIONAL AREA (%)



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Note: Manufacturing taxonomy adapted from Integrated Manufacturing Technology. 21st Century Manufacturing Taxonomy: [IMTI, 2003].

KEY FINDINGS

Applications and solutions that were more commonly used in our sample of firms surveyed:

- Process control & optimisation **~ 33% of instances**
- Production planning & control **~ 9.4% of instances**
- Material/product processing **~ 9% of instances**
- Process quality management **~ 7.1% of instances**
- Product design & definition **~ 5.7% of instances**

DIGITAL APPLICATIONS & SOLUTIONS THAT LED TO THE LARGEST IMPACT IN TOP 5 BUSINESS VALUE AREAS

Reduction of labour costs

Key applications
- Process design & definition (80%)
- Resource management (80%)
- Product design & definition (66%)

Reduction of defects and errors

Key applications
- Product design & definition (100%)
- Staff and workflow management (65%)
- Process design & definition (60%)

Reduction in material costs

Key applications
- Process design & definition (63%)
- Product development (50%)
- Process control and optimization (42%)

Increase outputs

Key applications
- Packaging & shipping (100%)
- Process control and optimization (33%)
- Assembly (13%)

Improved delivery & service performance

Key applications
- Staff and workflow management (75%)
- Product & service quality management (75%)
- Production planning & control (71%)

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(3) ‘HEATMAPS’

HEATMAPS

Heatmap 1:
Prevalence of applications

Tells us how often an application led to an impact on a particular type of business value

Heatmap 2:
Relevance of applications

Tells us how big the impact of an application was for each type of business value

HEATMAPS (EXAMPLE: LABOUR COSTS)

Heatmap 1: Prevalence of applications

Low → High

	Digital applications and solutions [HOW IS IT ACHIEVED]																				
	Manufacturing product & process design and development			Manufacturing process									Manufacturing infrastructure	Enterprise management							
Sources of business value [WHAT IS ACHIEVED]	Product design & definition	Product development	Process design & definition	Process quality management	Material pre/post processing	Input & waste management	Material/product processing	Assembly	Testing, inspection, validation	Packaging & shipping	Maintenance management	Process control and optimisation (including machine operation monitoring)	Operations infrastructure	Product and service quality management	Supply chain management	Production planning and control	Product lifecycle management	Staff and Workflow management	Demand forecasting/ inventory and delivery management	Resource management	Business operations
Increase revenue – Increase profit margin																					
Increase revenue – Increase sales of existing products																					
Increase revenue – Improve product performance / functionality																					
Increase revenue – Increase customer satisfaction																					
Increase revenue – Reduce time to market – Reduce prototyping/testing/design time																					
Increase revenue – Reduce time to market – Reduce overall time to market (including development time)																					
Reduce costs – Increase manufacturing efficiency – Reduce input use – Labour (time, effort)																					
Reduce costs – Increase manufacturing efficiency – Reduce input use – Material																					
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Reduce costs – Reduce maintenance cost																					
Reduce costs – Improve delivery and service performance																					
Reduce costs – Reduce equipment commissioning and tooling																					
Reduce working capital – Reduce inventory																					

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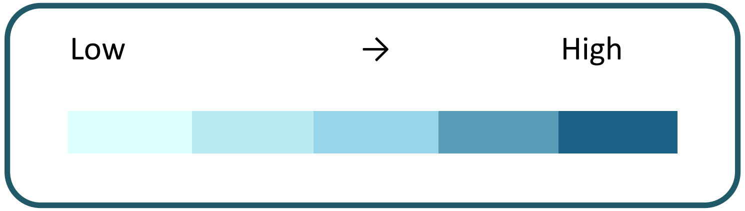
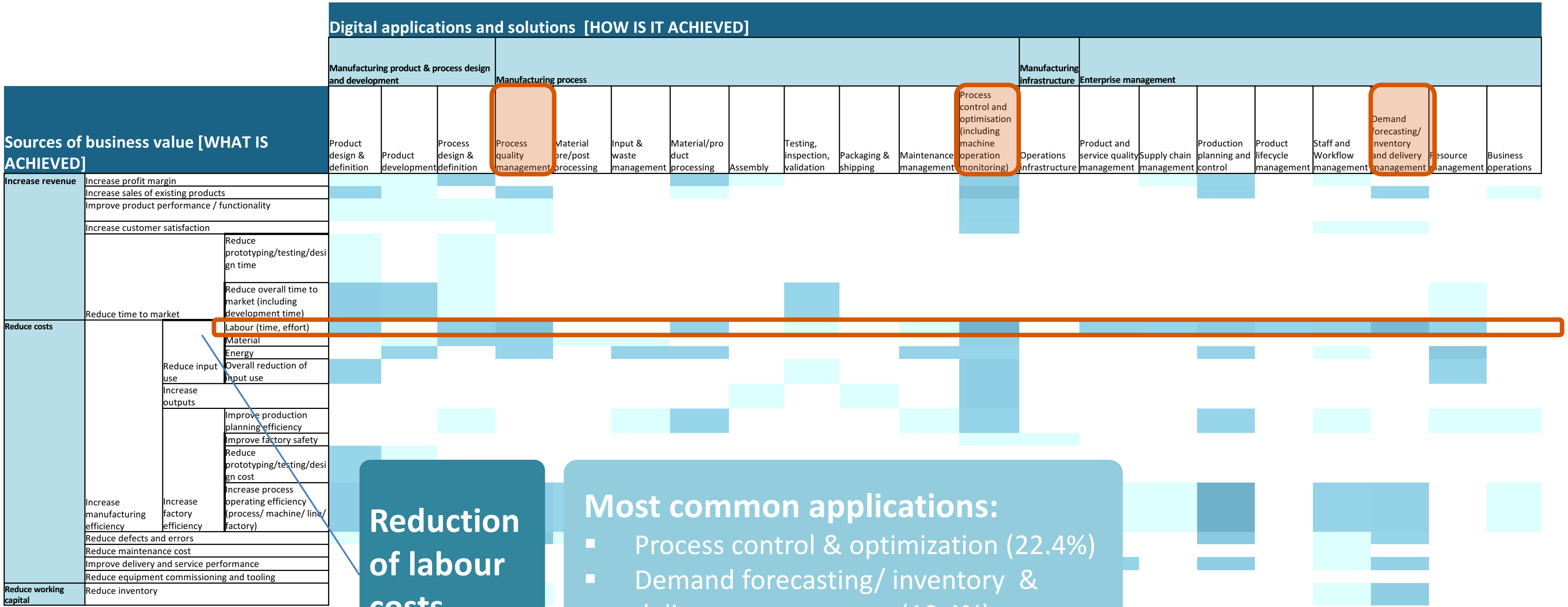
HEATMAPS

Heatmap 1: Prevalence of applications





Reduction of labour costs

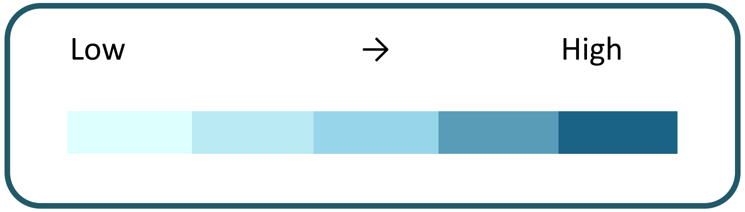
Most common applications:

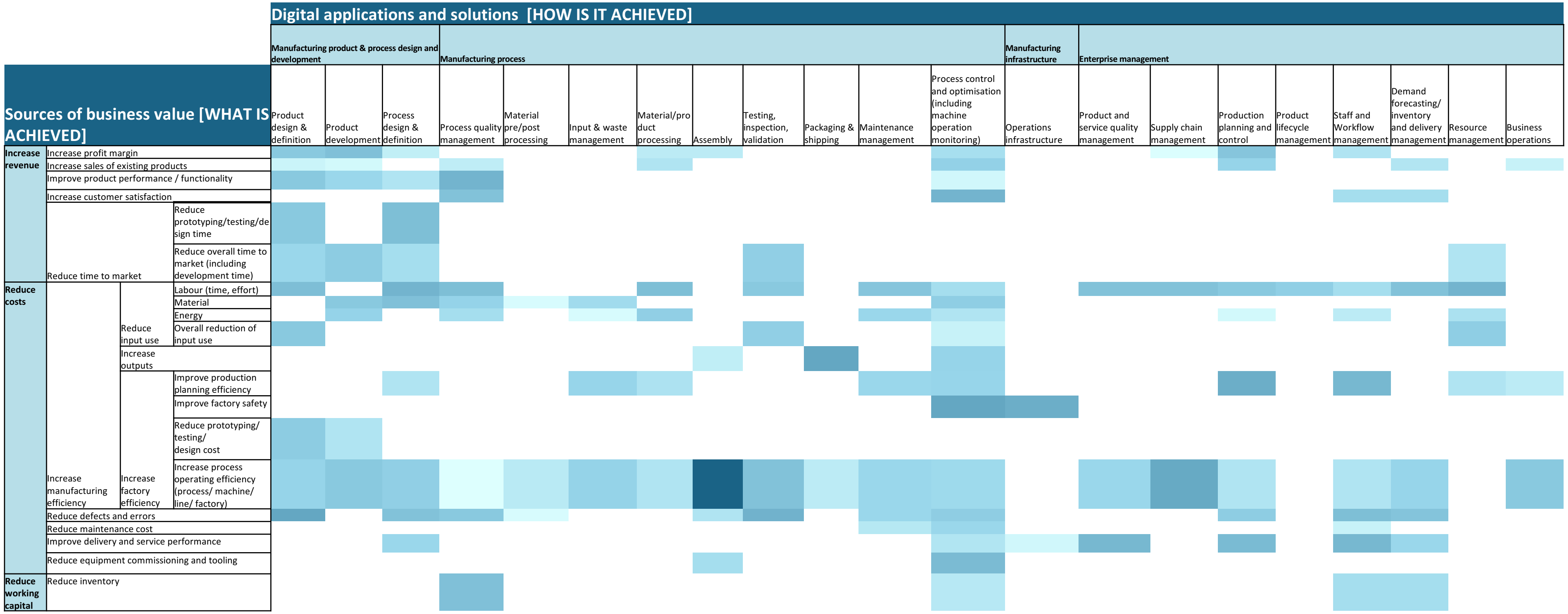
- Process control & optimization (22.4%)
- Demand forecasting/ inventory & delivery management (19.4%)
- Process quality management (13.4%)

Policy Links, 2018

HEATMAPS (EXAMPLE: LABOUR COSTS)

Heatmap 2: Relevance of applications



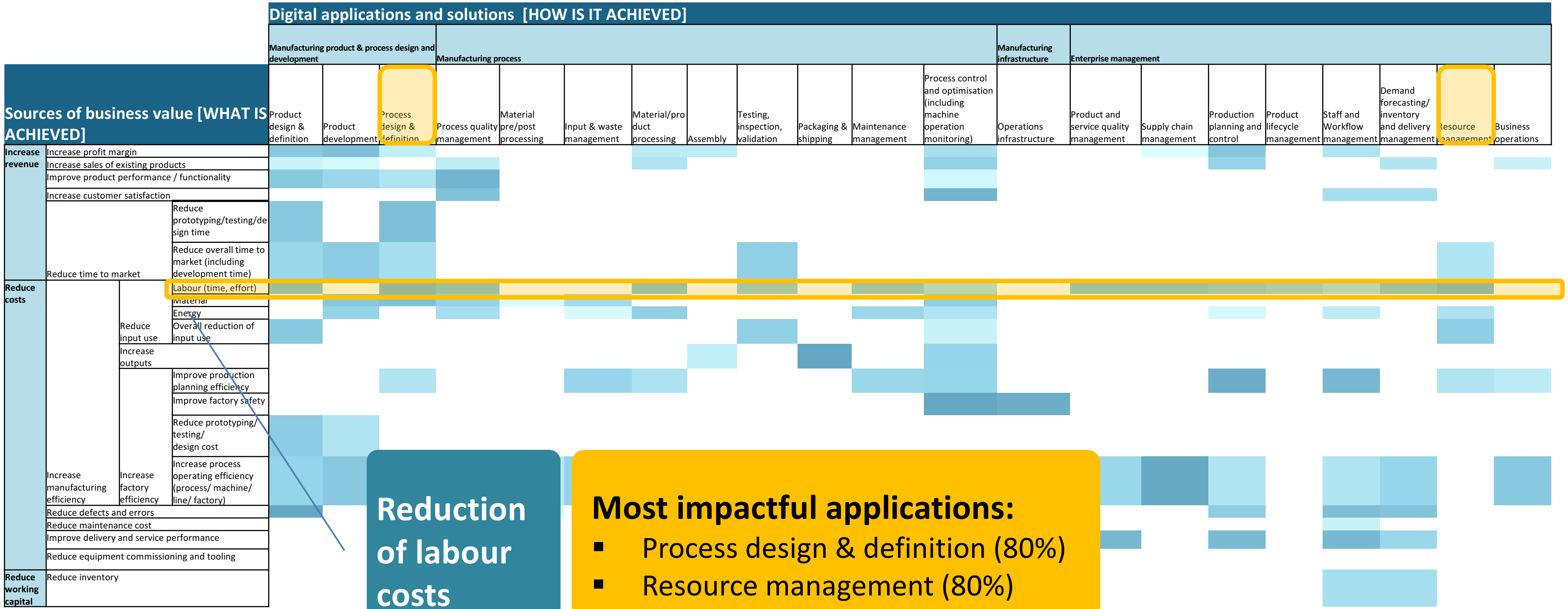


Policy Links, 2018

HEATMAPS (EXAMPLE: LABOUR COSTS)

Heatmap 2: Relevance of applications

Low → High



Reduction of labour costs

Most impactful applications:

- Process design & definition (80%)
- Resource management (80%)
- Product design & definition (66%)

Policy Links, 2018

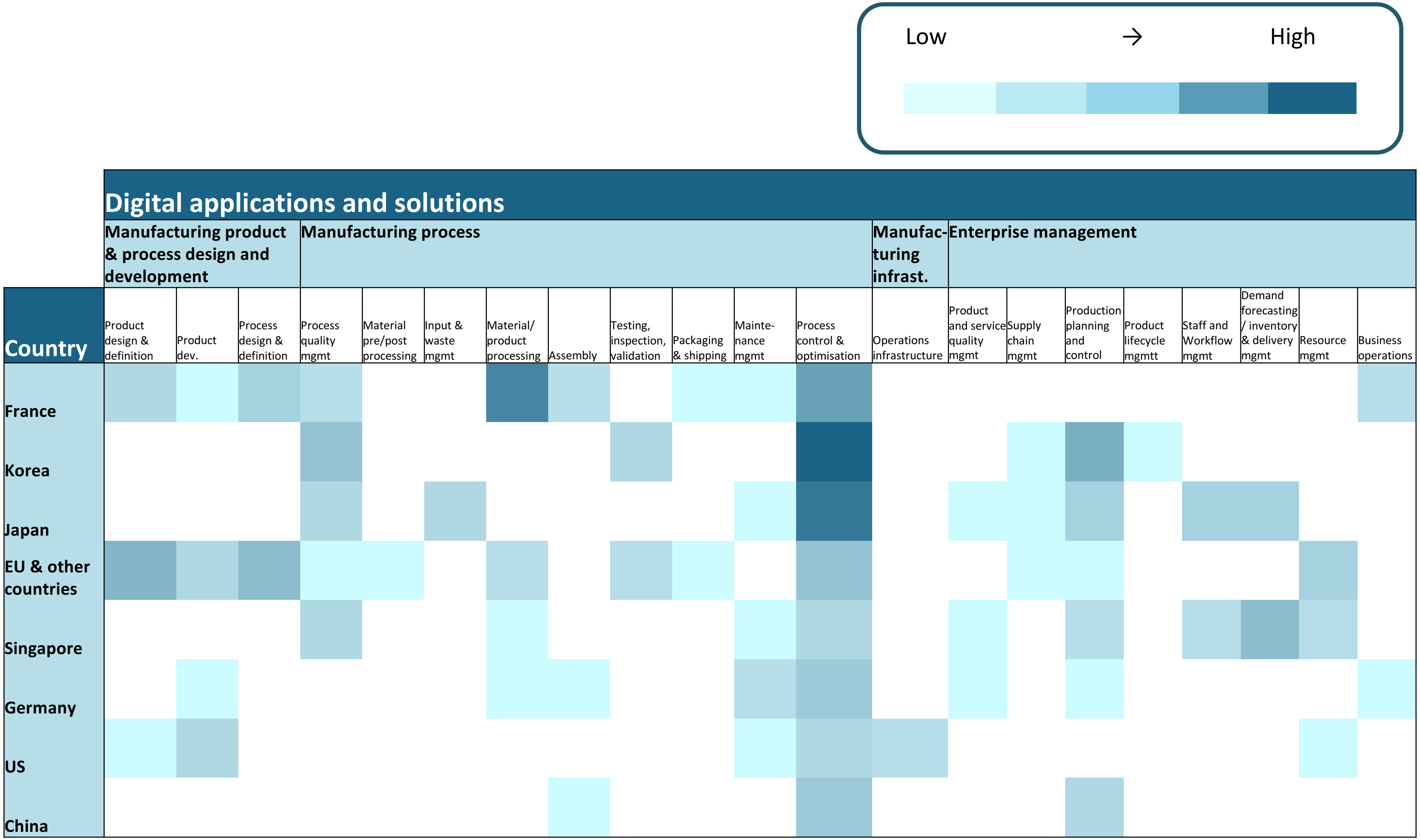
HEATMAPS (SELECTED EXAMPLES)

Reduction of labour costs	**Most common applications:** ▪ Process control & optimization (22.4%) ▪ Demand forecasting/ inventory & delivery management (19.4%) ▪ Process quality management (13.4%)	**Most impactful applications:** ▪ Process design & definition (80%) ▪ Resource management (80%) ▪ Product design & definition (66%)
Reduction of defects and errors	**Most common applications:** ▪ Process control & optimization (40%) ▪ Process quality management (20%) ▪ Production planning & control (17.5%)	**Most impactful applications:** ▪ Product design & definition (100%) ▪ Staff and workflow management (65%) ▪ Process design & definition (60%)
Reduction in material costs	**Most common applications:** ▪ Process control & optimization (36.4%) ▪ Process design & definition (18.2%) ▪ Process quality management (18.2%)	**Most impactful applications:** ▪ Process design & definition (63%) ▪ Product development (50%) ▪ Process control & optimization (42%)
Increase outputs	**Most common applications:** ▪ Process control & optimization (71.4%) ▪ Packaging & shipping (14.3%) ▪ Assembly (14.3%)	**Most impactful applications:** ▪ Packaging & shipping (100%) ▪ Process control & optimization (33%) ▪ Assembly (13%)
Improved delivery & service performance	**Most common applications:** ▪ Process control & optimization (33.3%) ▪ Production planning & control (20.8%) ▪ Demand forecasting/ inventory & delivery management (16.7%)	**Most impactful applications:** ▪ Staff & workflow management (75%) ▪ Product & service quality management (75%) ▪ Production planning & control (71%)

ANALYSIS BY COUNTRIES

ANALYSIS BY COUNTRIES

USE OF APPLICATIONS & SOLUTIONS ACROSS COUNTRIES



Policy Links, 2018

ANALYSIS BY COUNTRIES

USE OF APPLICATIONS & SOLUTIONS ACROSS COUNTRIES

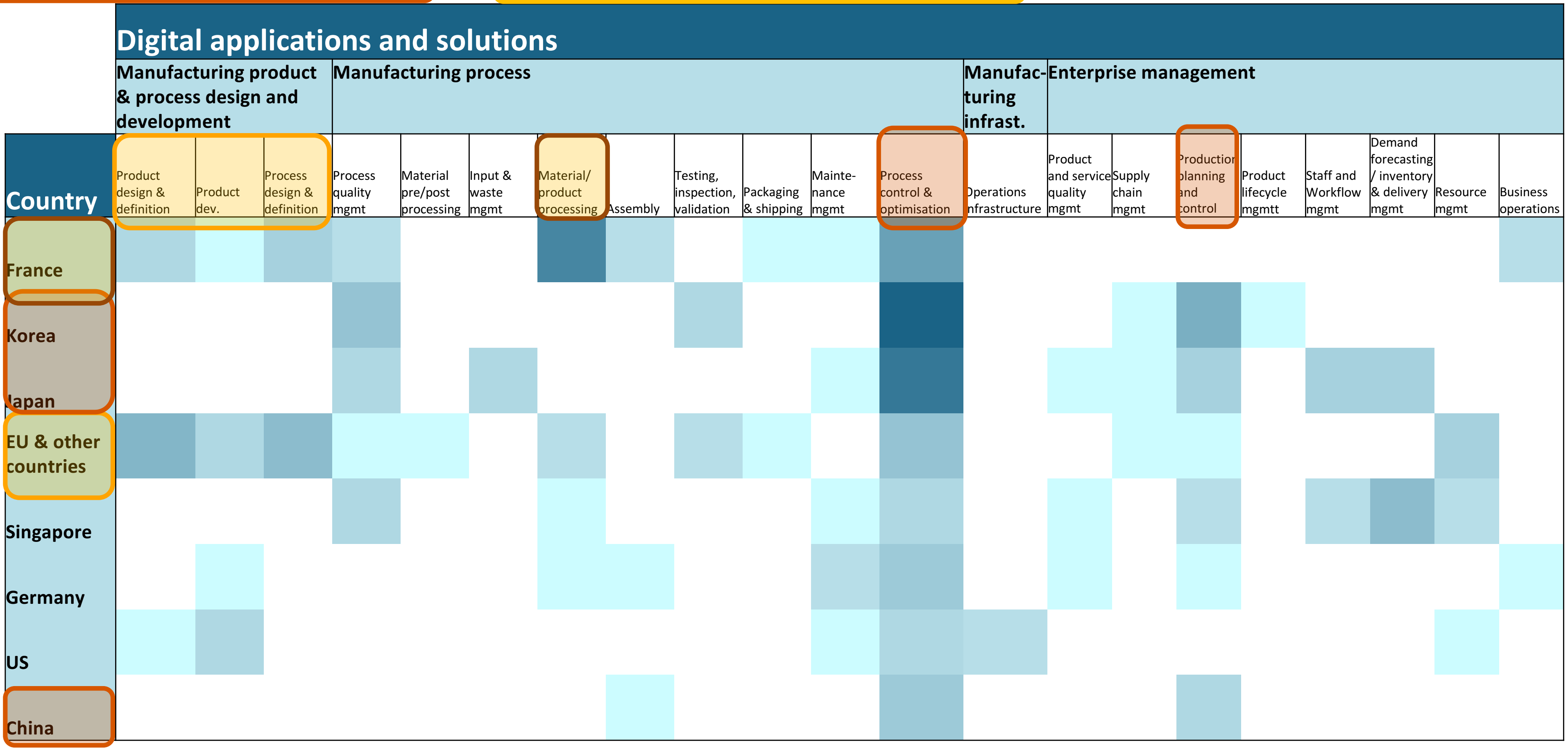
Common emphasis across countries:

- Process control & optimization
- Production planning & control

Different national emphasis:

- Product/process design in Europe
- Process control & optimization in Korea, Japan, China
- Material product processing in France

Low → High



Policy Links, 2018

UNIVERSITY OF CAMBRIDGE
Department of Engineering
IfM Education and Consultancy Services

'DEEP DIVES': COUNTRIES AND APPLICATIONS
MOST COMMON APPLICATIONS EACH COUNTRY

France
- Material/product processing
- Process control and optimisation
- Process design and definition

Korea
- Process control and optimisation
- Production planning and control
- Process quality management

Japan
- Process control and optimisation
- Production planning and control
- Demand forecasting/ inventory and delivery management
- Staff and workflow management

EU & other countries
- Product design and definition
- Process design and definition
- Process control and optimisation

Singapore
- Demand forecasting/ inventory and delivery management
- Process quality management
- Process control and optimisation

Germany
- Process control and optimisation
- Maintenance management
- Product development*

*Same position as Material/product processing, Assembly, Product and service quality management, Production planning and control, Business operations

US
- Product development
- Process control and optimisation
- Operations infrastructure

China
- Process control and optimisation
- Production planning and control
- Assembly

Policy Links, 2018

RESULTS

Indicators of the practical impact of digital manufacturing were obtained from three main sources:

a) STRATEGIES & REPORTS AND STUDIES FROM NATIONAL INITIATIVES
b) USE CASES (FIRM-LEVEL ADOPTION)
c) POLICY & ACADEMIC LITERATURE

SOME RESULTS FROM THE ACADEMIC LITERATURE

Reference	Impact	Indicator	Value
Kromann, L *et al.*. (2016).	Automation of production processes was found to be positively and significatly correlated to productivity	Increased **Labour productivity** between 1997-2007 in the manufacturing sector due to investments in **industrial robots.**	**35%**
Brynjolfsson, E. *et al.* (2011)	Firms that adopt **data-driven decision making" (DDD)** have a higher market value, mostly related to the IT Capital.	Adoption of **"data-driven decision making" (DDD)** increases **firm's productivity**	**5-6%**
Graetz, G. & Michales, G. (2015)	An estimated 0.4 percentage points of annual GDP growth was added by **robotics** between 1993 and 2007	**Annual GDP growth due to robotics**	**0.4 percentage** points
Schuh, G. *et al* (Eds.) (2017).	Value creation potential of **Industrie 4.0 between 100-150 billion euros over the next 5 years** in Germany.	–	–
Smart Service Welt Working Group/acatech (Eds.). (2015)	Generated additional value-added from Europe's digital single market up to **500 billion euros by 2020.**	–	–

DISCUSSION AND CONCLUSIONS

DISCUSSION

- **Strong focus on 'Manufacturing Process' applications & solutions within one enterprise**
  - → Few applications across multiple enterprises
- **Choice of applications influenced by focus of Agency / Institution**
  - → But also by definition of 'digitalisation' adopted
- **Some experts suggested influence of complexity on current levels of adoption**
  - → Some SMEs prefer simpler applications like *visualisation for production planning* and *single-process optimisation solutions*
  - → Opportunity to distinguish between 'new and old' applications & solutions - and where the impact might come in the future

DISCUSSION

- **Difference between SMEs and large firms**
  - → "Larger companies have invested in digital solutions in the past, so they are expected to achieve less significant productivity improvements" [1]

- **And between sectors – in particular country context**
  - → "Sectors like shipbuilding, mechanical engineering, smart grids, etc. need to change whole infrastructures and supply chains… benefits in these sectors are likely to take place only after 2025." [1]

- **Attention to collaborative platforms**
  - → Role of collaborative platforms (and large firms) in digital adoption along the supply chain

[1] KIET (2017). The Influences & Challenges of the Fourth Industrial Revolution on Korean Major Industries. Korea Institute for Industrial Economics & Trade.

DISCUSSION

- **Open Questions**
  - → Where can the UK can genuinely get ahead of competitors?
  - → Will many benefits disappear if everyone makes the same improvements?
  - → What is the relationship between productivity and measures of international competitiveness (market shares, etc.)?

RELEVANCE

- **Structure for future evidence collection:** The suggested approach could be used to structure emerging evidence – as more data is generated internationally.
- **Insights into factors/practices facilitating adoption:** While not the focus of the project, some international effective practices identified (use cases; cost/ROI; training support).
- **Reference for policy evaluation:** Estimations of expected benefit obtained across different applications can provide useful information for policy evaluation.

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REFERENCES

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